

Growth and maturity of brown frogs, *Rana arvalis* and *Rana temporaria*, in central Poland

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Growth of two brown frog species, *Rana arvalis* and *Rana temporaria*, was studied in nature and in captivity. In both species, growth was fastest in the first two years, maturity was reached in the second year, and gametes were released after the second hibernation. Individuals of *Rana arvalis* matured earlier than those of *Rana temporaria*, and in some males of *Rana arvalis* the sexual features were visible already before the first hibernation.

INTRODUCTION

The two species of brown frogs *Rana temporaria* and *Rana arvalis* belong to the common amphibians in central Europe. Data on their growth and sexual maturity are numerous, but opinions on this subject are controversial. KRIVOSHEYEV, OPENKO & SHABANOVA (1960) suggested that they grow most rapidly in the third (*Rana arvalis*) or in the fourth year (*Rana temporaria*), that is, in the year of reaching maturity. Most other authors state that they grow very quickly in the first and in the second year, whereas growth decreases after maturation (GISLÉN & KAURI, 1959; KLEINENBERG & SMIRINA, 1969; TOMASIK, 1969; VAN GELDER & OOMEN, 1970; LOMAN, 1978; GIBBONS & MCCARTHY, 1984; CHMELEVSKAJA, 1985; RYSER, 1988; among others). They report that the frogs can reach maturity between the second and the fourth year of their lives and release gametes for the first time after two to four hibernations.

In 1965 we found a surprisingly small adult *Rana arvalis* male (37.5 mm, snout-vent length) in a breeding aggregation, and in 1977 we caught a very small female of *Rana arvalis* (39.5 mm) in amplexus, which subsequently laid 404 eggs in an aquarium. These data prompted us to observe brown frogs more precisely.

In the present paper we review available data and compare them with our results, which suggest that growth and sexual maturity in these frog species depend not only on geographical distribution, but also on environmental conditions.

MATERIAL AND METHODS

This paper on brown frogs arose as a by-product during the study of European water frogs (BERGER & BERGER, 1992). The observations are not homogeneous, because they were carried out in different years (1963-1989), on different populations and in various environments. The study areas are situated within the drainage of the Warta river in central Wielkopolska. This region forms a rather homogeneous geographical and climatic unit (BARTKOWSKI, 1970).

Newly metamorphosed froglets of both species, which are the most common amphibians in the region (BERGER, 1987), were gathered near water bodies in which they lived as tadpoles. Individuals were killed and preserved in 3% formaldehyde. They originated from the vicinity of Poznań and the Biological Field Station of our Institute in Turew (about 40 km south of Poznań), and from Jaskółki near Ostrów Wielkopolski (about 100 km south-east of Poznań). In two localities the froglets were gathered every two or three weeks, in the others they were caught during researches of water frogs. We were not able to gather any data on older brown frogs in nature, because we did not mark them and it was not possible to estimate their age by their body length.

During some years froglets were reared in captivity. The frogs were measured with an accuracy of 0.1 mm (snout-vent length) after capture and later on every spring until their death; some were measured twice in a year (fig. 2). We marked them collectively or individually by toe-clipping. In 1986, about 20,000 tadpoles of *Rana arvalis* were put into 10 basins which contained 200-350 l of water with plants and mud from a pond. The basins were located in a fenced enclosure of 10 × 10 m in a garden. These tadpoles and frogs never received any special food during their life-time. It was much easier to keep *Rana arvalis* than *Rana temporaria*. Froglets of the former species were more vital and usually survived some years in captivity, whereas those of the latter usually perished before or during the first hibernation.

RESULTS

GROWTH OF FROGS IN NATURE

After metamorphosis, the body length of *Rana arvalis* and *Rana temporaria* froglets was rather similar and averaged about 14-16 mm in the studied localities (fig. 1). In autumn, individuals of *Rana temporaria* were much larger than those of *Rana arvalis*: the first reached about 35 mm (range 24-42 mm), and the second about 24 mm (range 16-32 mm) in body length. In other localities their body length in autumn was as follows: in Stawa Wielkopolska near Poznań (Sept. 14, 1962), *Rana arvalis* measured 17.2-30.2 mm (mean 22.45, N = 53), and *Rana temporaria* 17.8-32.0 mm (mean 24.10, N = 19); in Zbęchy near Turew (Sept. 7, 1978), *Rana arvalis* measured 22.7-34.0 mm (mean 28.10, N = 17), and *Rana temporaria* 24.3-42.5 mm (mean 34.20, N = 28).

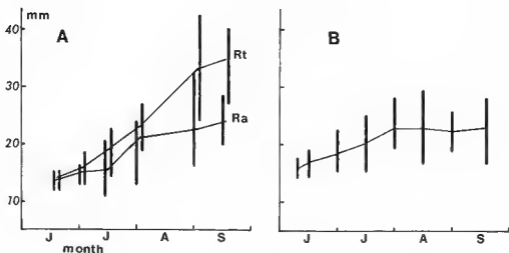


Fig. 1. — Growth of brown frogs in nature. (A) Rogaczewo near Turew, 1978: Rt, *Rana temporaria* (N = 59); Ra, *Rana arvalis* (N = 130); (B) Poznań-Naramowice, 1963. *Rana arvalis* (N = 512). Mean values of body length are joined by lines, extreme sizes of froglets are indicated by vertical bars.

Froglets after first hibernation were collected in two localities. In Rogaczewo (May 5, 1978), we gathered 66 froglets of *Rana arvalis* with body length of 18.7-31.0 mm (mean 25.12; see fig 1), and in Turew park (April 20, 1980), we caught froglets of both species. *Rana arvalis* measured 29.0-40.0 mm in body length (mean 35.70, N = 3), and *Rana temporaria* 36.0-52.0 mm (mean 44.40, N = 65).

GROWTH OF FROGS IN CAPTIVITY

Froglets from nature (fig. 2)

The froglets from Jaskółki which were caught in autumn (Sept. 5, 1988) were marked individually, and the others which were caught during metamorphosis were marked collectively. The following year, initially smaller individuals grew more rapidly than larger ones (Table I).

In summer after the first hibernation the sexual features appeared in all surviving frogs of both species, and after the second hibernation all frogs that were left released gametes. The three females of *Rana arvalis* from Poznań-Jumkowo measured 41.5, 42.6 and 46.5 mm in body length and laid 141, 168 and 728 eggs respectively; those from Zbęchy measured 44.0, 49.5, 52.0 and 58.0 mm in body length and laid 692, 1077, 1434 and 2055 eggs respectively.

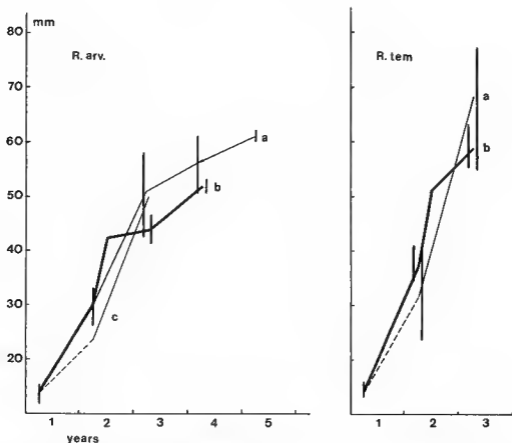


Fig. 2. — Growth of brown frogs in captivity.

R. arv., *Rana arvalis* from (a) Zbęchy near Turew, 1978 ($N \approx 26$); only two individuals survived the fifth hibernation; (b) Poznań-Junikowo, 1970 ($N = 32$), only two frogs survived the third hibernation; (c) Jaskółki near Ostrów Wielkopolski, 1988 (one female only).

R. tem., *Rana temporaria* from (a) Jaskółki near Ostrów Wielkopolski, 1988 ($N = 20$); 11 frogs survived the first hibernation; (b) Poznań, 1974 ($N = 30$); only five frogs survived the second hibernation.

Individuals of *Rana arvalis* from Poznań-Junikowo and *Rana temporaria* from Poznań were measured twice in the second season. Individuals from Jaskółki were removed from the rearing area on July 30.

Among *Rana temporaria* from Poznań only one female of 63.0 mm body length laid 972 eggs spontaneously with the only male which survived the winter. The other three females with body length of 56-58 mm were caught and after dissection we found mature ova in their ovisacs which were ready to be shed (627, 730 and 821 eggs).

The mean body length of *Rana arvalis* from Poznań-Junikowo reached 29.9 mm after the first hibernation, 42.3 mm in July, and 44.0 mm in the spring of the next year; this

Table I. -- Growth of *Rana temporaria* individuals in captivity. The frogs are arranged according to body length at the day of capture in Jaskółki near Ostrów Wielkopolski.

| Females | | | | | Males | | | | |
|---------------|--------------|--------------|--------|-----|----------------|--------------|--------------|--------|-----|
| No of frog | Body length | | Growth | | No. of frog | Body length | | Growth | |
| | Sept. 5 1988 | July 30 1989 | mm | % | | Sept. 5 1988 | July 30 1989 | mm | % |
| 16 | 27.2 | 65.0 | 37.8 | 139 | 14 | 25.0 | 55.0 | 30.0 | 120 |
| 20 | 27.8 | 76.0 | 48.2 | 174 | 21 | 25.2 | 63.0 | 37.0 | 147 |
| 22 | 28.0 | 71.0 | 43.0 | 154 | 27 | 37.8 | 77.0 | 39.2 | 104 |
| 15 | 32.0 | 71.0 | 39.0 | 122 | 13 | 39.5 | 67.0 | 27.5 | 70 |
| 24 | 34.0 | 68.0 | 34.0 | 100 | 23 | 40.0 | 66.0 | 26.0 | 65 |
| 26 | 36.3 | 71.5 | 35.2 | 97 | | | | | |
| Means | 30.9 | 70.4 | 39.5 | 131 | | 35.5 | 65.6 | 31.9 | 101 |

means that within the first period they grew about 12.4 mm and in the second only 1.7 mm. The *Rana temporaria* from Poznań grew in a similar way. They averaged 37.0 mm in body length after the first hibernation, 51.0 mm on June 12, and 58.5 mm in the spring of the next year. Within the first period they grew about 22.6 mm and in the second only 14.0 mm.

Frogllets from tadpoles reared in captivity

On April 4, 1986, we brought 23 clumps of spawn of *Rana arvalis* from Poznań-Naramowice pond, which contained 1171-2563 eggs (mean 1737). Sixteen clumps were kept in containers outdoors, the others in the laboratory. During their development the temperature decreased to 5°C below zero at night. Percentage of embryos which reached tadpole stage was as follows: in the laboratory 78.6-97.2 % (mean 88.2 %), and outdoors 8.5-88.1 % (mean 38.1 %). All tadpoles were mixed and distributed into basins in the enclosure in Jaskółki in which there were no brown frogs before. The first metamorphosed individuals appeared on June 2, but in July tadpoles could still be seen in basins. At the end of September we caught three froglets (40-45 mm in body length) with typical male features (blue colour and nuptial pads).

The following year, the frogs formed a breeding aggregation in the largest basin, but by the end of April there were no eggs. In the basin we found 14 adult *Rana arvalis* males with 40.0-48.6 mm in body length (mean 44.8), but there were no females. Juvenile individuals were also found in the rearing area: 23 females with body length of 19.0-42.8 mm and 14 males with body length of 15.5-39.5 mm. The ovaries of these females were in bud stage, and in the testes of some juvenile males (33.0-39.5 mm in body length) moving spermatozoa were present.

DISCUSSION

The period of metamorphosis of tadpoles of *Rana arvalis* and *Rana temporaria*, which are explosive early spring breeders, is usually very short (VAN GELDER & OOMEN, 1970; RYSZKOWSKI & TRUSZKOWSKI, 1975). This suggests that individuals of these species should form compact age groups (KRIVOSHEYEV, OPENKO & SHABANOVA, 1960, GAJZAUSKIENE, 1966; HEUSSER, 1970). However, their growth rates in nature (VAN GELDER & OOMEN, 1970; LOMAN, 1978; CHMELEVSKAJA, 1985; fig. 1) and in captivity (SMIRINA, 1980, 1986) are quite variable and opinions on their age and sexual maturity are often contradictory.

The data of VAN GELDER & OOMEN (1970) and LOMAN (1978), and our results suggest that in nature only the yearlings can be identified by body length, whereas the division of older frogs into age classes is impossible by body length alone. KLEINENBERG & SMIRINA's (1969) skeletochronological studies corroborate this conclusion. They found that individuals of *Rana temporaria* caught near Moscow in June formed three size classes, but only one class which contained the smallest individuals (after the first hibernation) was homogeneous, whereas the other two classes contained individuals which were 2-9 years old. Other authors (MINA, 1974; ISHCENKO & LEDENTZOV, 1985, 1986) obtained similar results.

Our observations show that individuals of both species grew most rapidly at the beginning of the second season (May-June, fig. 2, Table I), or before reaching maturity. Within yearlings of *Rana temporaria* in the Wielkopolska region, however, we observed considerable differentiation in autumn. Their mean body length ranged from 24.10 mm in Sława Wielkopolska to 44.40 mm in Turew (see SMIRINA, KLEVEZAL & BERGER, 1986). The conditions in our rearing area, in which the yearlings reached intermediate body lengths (fig. 1-2), are therefore likely to have been close to those in nature. To this extent, our observations on frogs in captivity can be compared with those obtained by others in wild.

Our data with regard to sexual maturity are also not always in agreement with other authors. Opinions on this problem are differentiated and data which are reported by many authors refer mostly to *Rana temporaria*.

According to GIBBONS & MCCARTHY (1984), in west Ireland most of the individuals in the breeding aggregations of *Rana temporaria* were two years old frogs (84 % of the males and 52 % of the females). In Britain also numerous such frogs were found in the breeding time (BEEBEE, 1980; COOKE, 1981). However, near Moscow in Russia (CHMELEVSKAJA, 1985), near Berne in Switzerland (RYSER, 1986, 1988) and in southern Sweden (LOMAN, 1976, 1978) so young individuals were extremely rarely present in breeding aggregations. Some others suggest that individuals of this species reach maturity in the third (HEUSSER, 1970; MINA, 1974) or in the fourth year (KLEINENBERG & SMIRINA, 1969). In our rearing (fig. 2, Table I), however, *Rana temporaria* reached maturity during the second season and after the second hibernation released gametes as two years old frogs. These results corroborate TOMASIK's (1969) opinion on Polish *Rana temporaria*.

The data on *Rana arvalis* are very scanty. ISHCENKO & LEDENTZOV (1985, 1986) found that in the breeding populations near Sviardlovsk in Russia only few individuals

(about 1 %) were two years old. TOMASIK (1969) also supposes that in Poland *Rana arvalis* can reach maturity in the second year. According to our results all individuals of *Rana arvalis* in rearing reached maturity in the second season. Other authors suggested, however, that individuals of this species mature later: in southern Sweden in the third or in the fourth year (LOMAN, 1976, 1978), and in the Netherlands in the third year (VAN GELDER & OOMEN, 1970). The latter authors report, however, that at the end of the second season most frogs had more than 40 mm in body length and at that time it was possible to distinguish males from females. This statement suggests that such frogs were mature and took part in the breeding aggregations as two years old animals.

The growth of *Rana arvalis* and *Rana temporaria* froglets in the first year is highly differentiated not only in Sweden (LOMAN, 1976, 1978), but also in the Netherlands (VAN GELDER & OOMEN, 1970), in Russia (CHMELEVSKAYA, 1985) and in Poland. Near Poznań in every locality and nearly in every sample, including froglets after the first hibernation, there were very large and very small individuals. The situation was, however, reversed in the second year of their life: the growth of small froglets was much faster than that of large ones (Table I; see also VAN GELDER & OOMEN, 1970). Similar observations which are consistent with the "compensation growth phenomenon" in animals (MINA & KLEVEZAL, 1976) have been observed in some other anuran species (JAMESON, 1956, BERGER, 1970; PŁYTYCZ & BIGAJ, 1985; BERGER & RYBACKI, unpublished data), which suggests that this phenomenon may be rather common in Amphibia.

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